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(54) **VARIABLE VALVE ACTUATOR ASSEMBLY HAVING A SECONDARY ACTUATOR**

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(58) **Field of Search** .... 123/90.15, 90.16, 123/90.17; 74/661, 665 A, 665 B, 665 C, 665 D; 92/2

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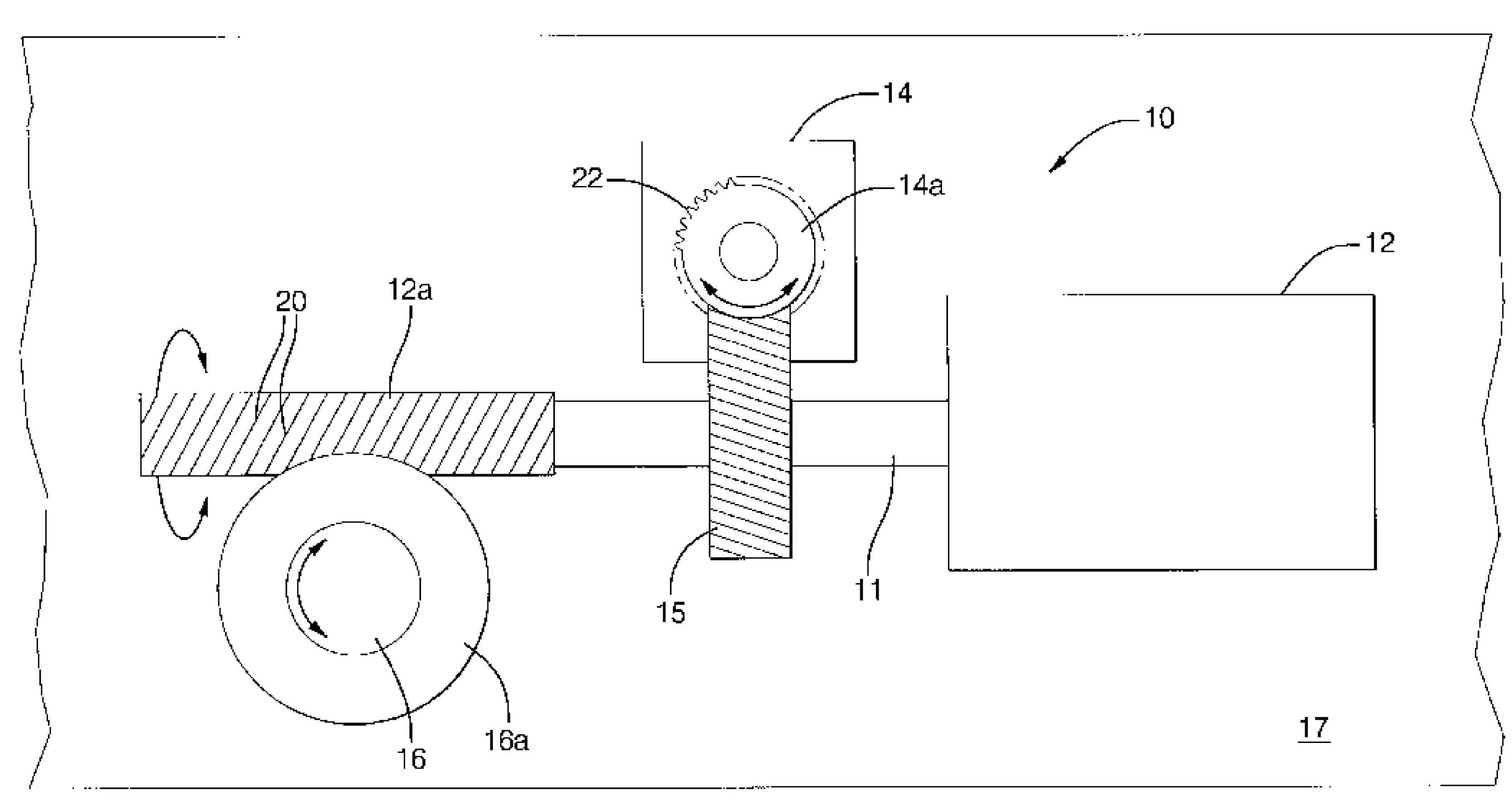
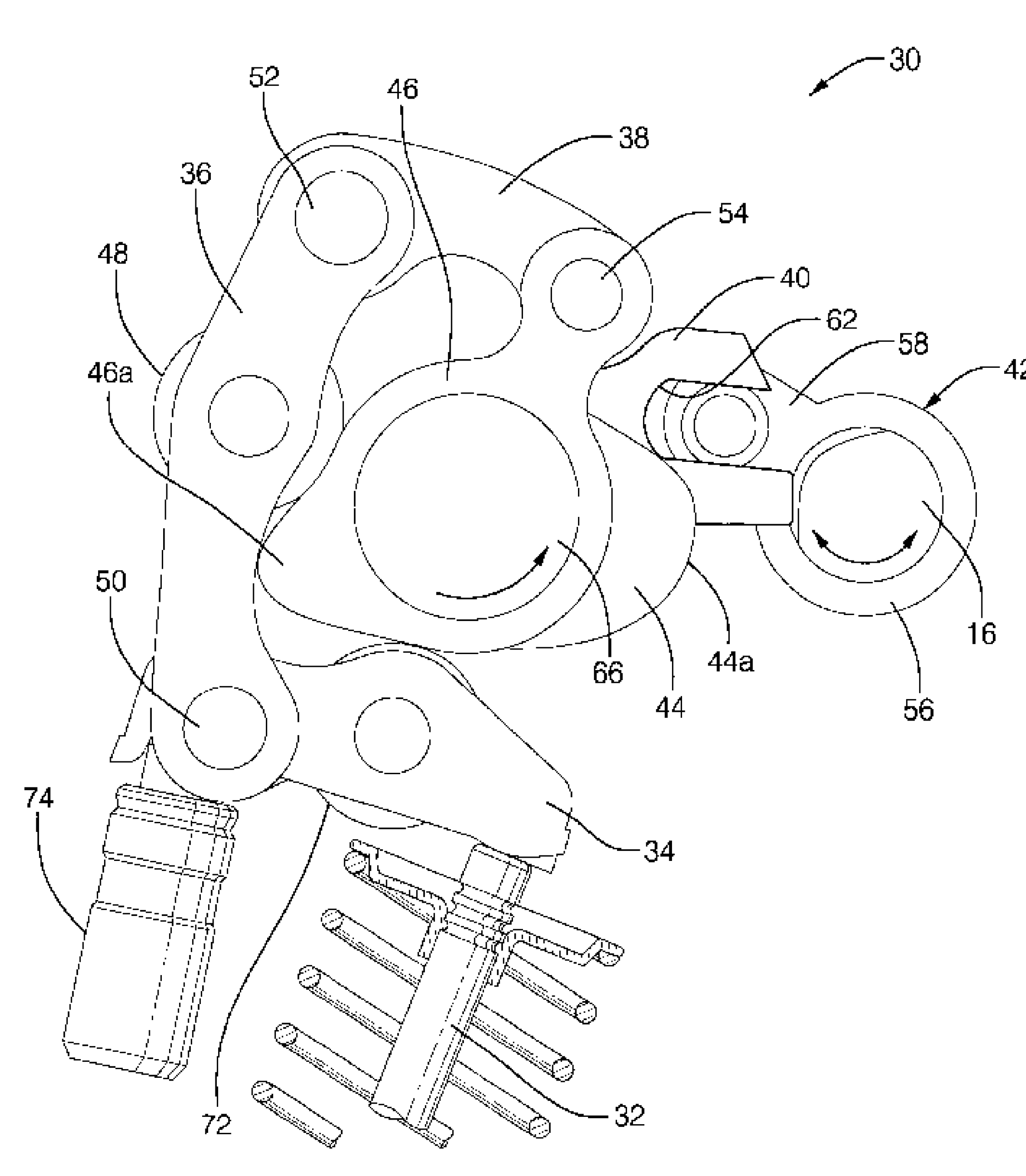
(57) **ABSTRACT**

A variable valve actuator assembly includes a main actuator, a secondary actuator and an actuator shaft. The actuator shaft is coupled to each of the main actuator and the secondary actuator. The main actuator and the secondary actuator are each separately and independently selectable for driving the actuator shaft to rotate.

10 Claims, 3 Drawing Sheets





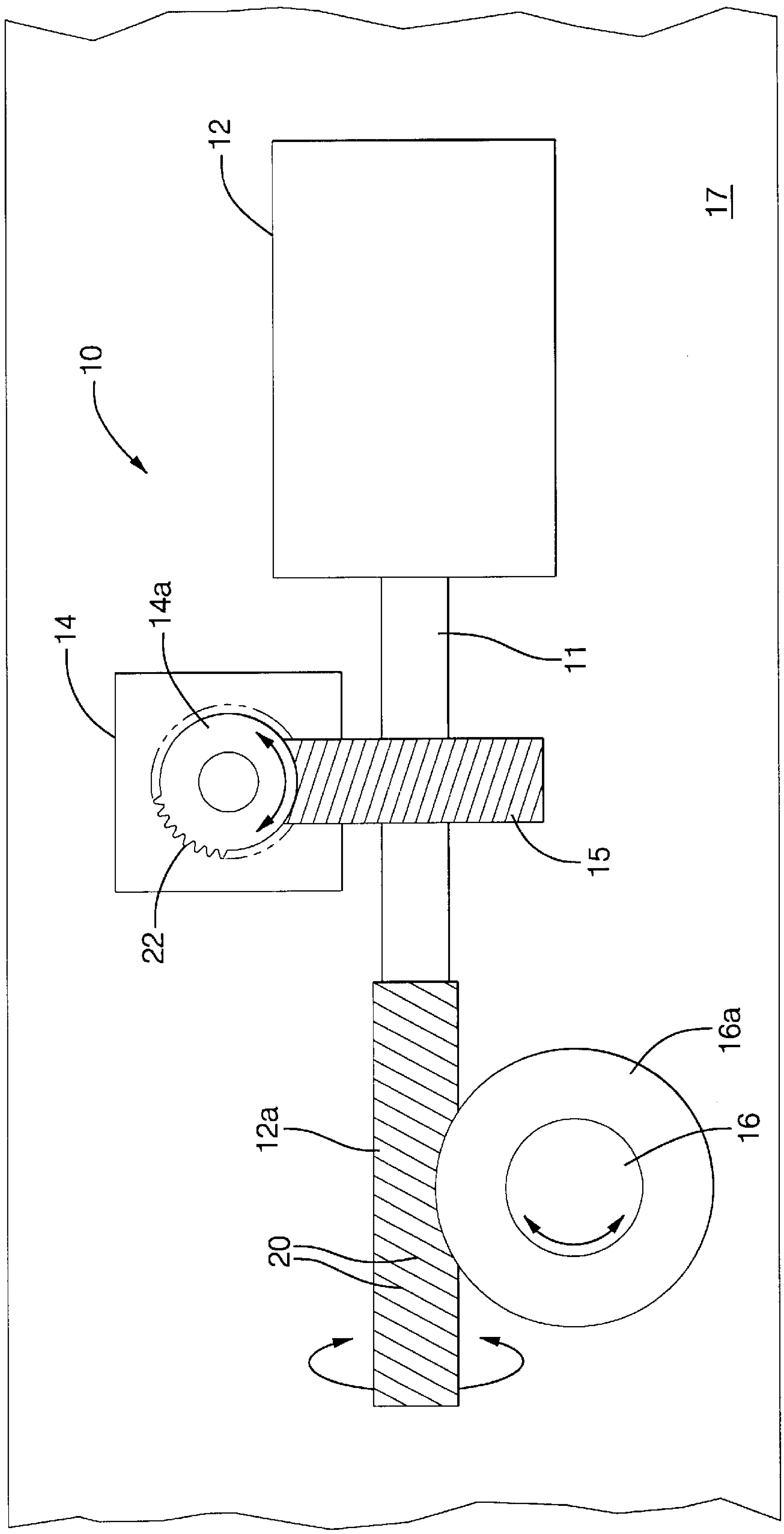


FIG. 1

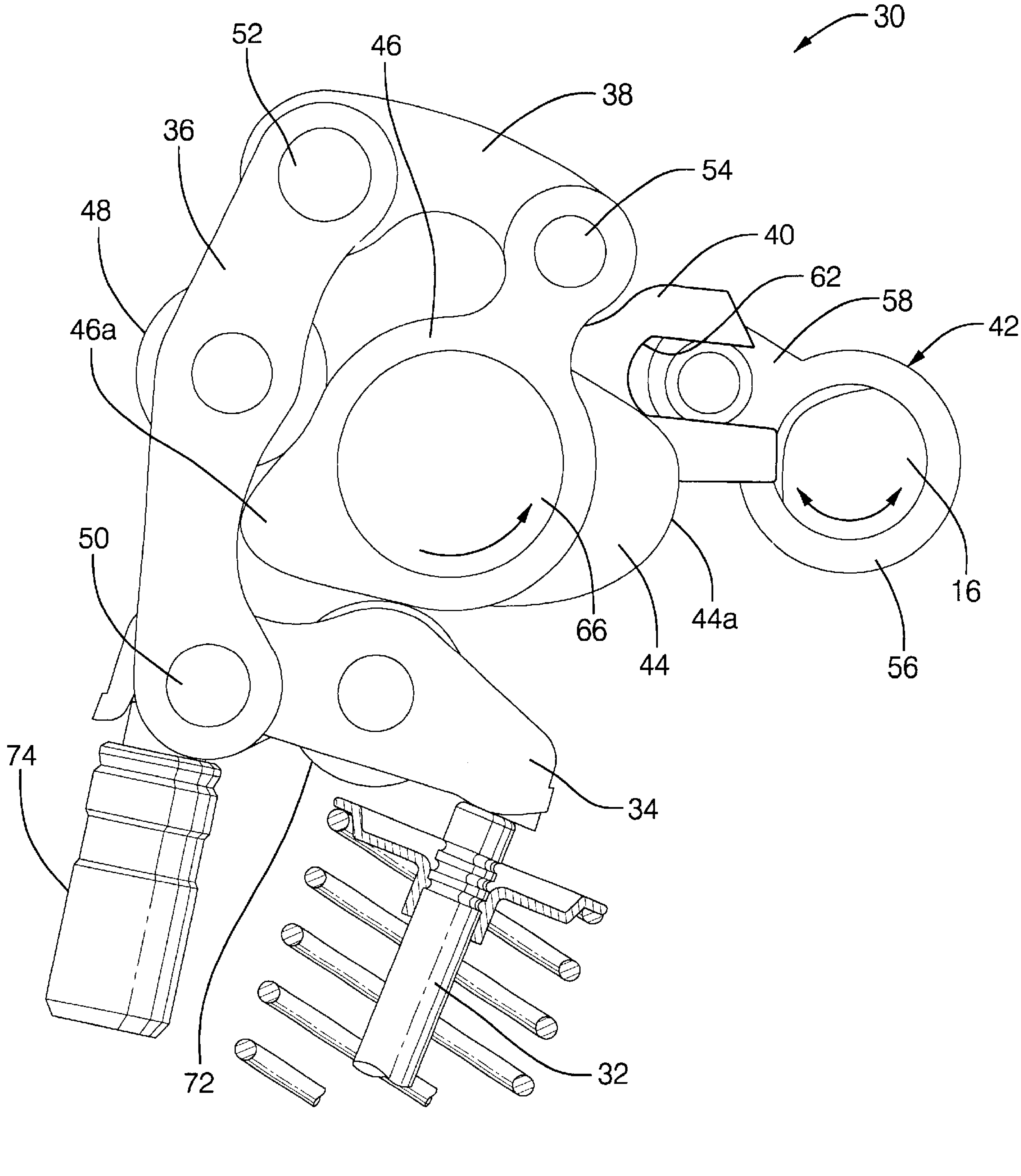


FIG. 2

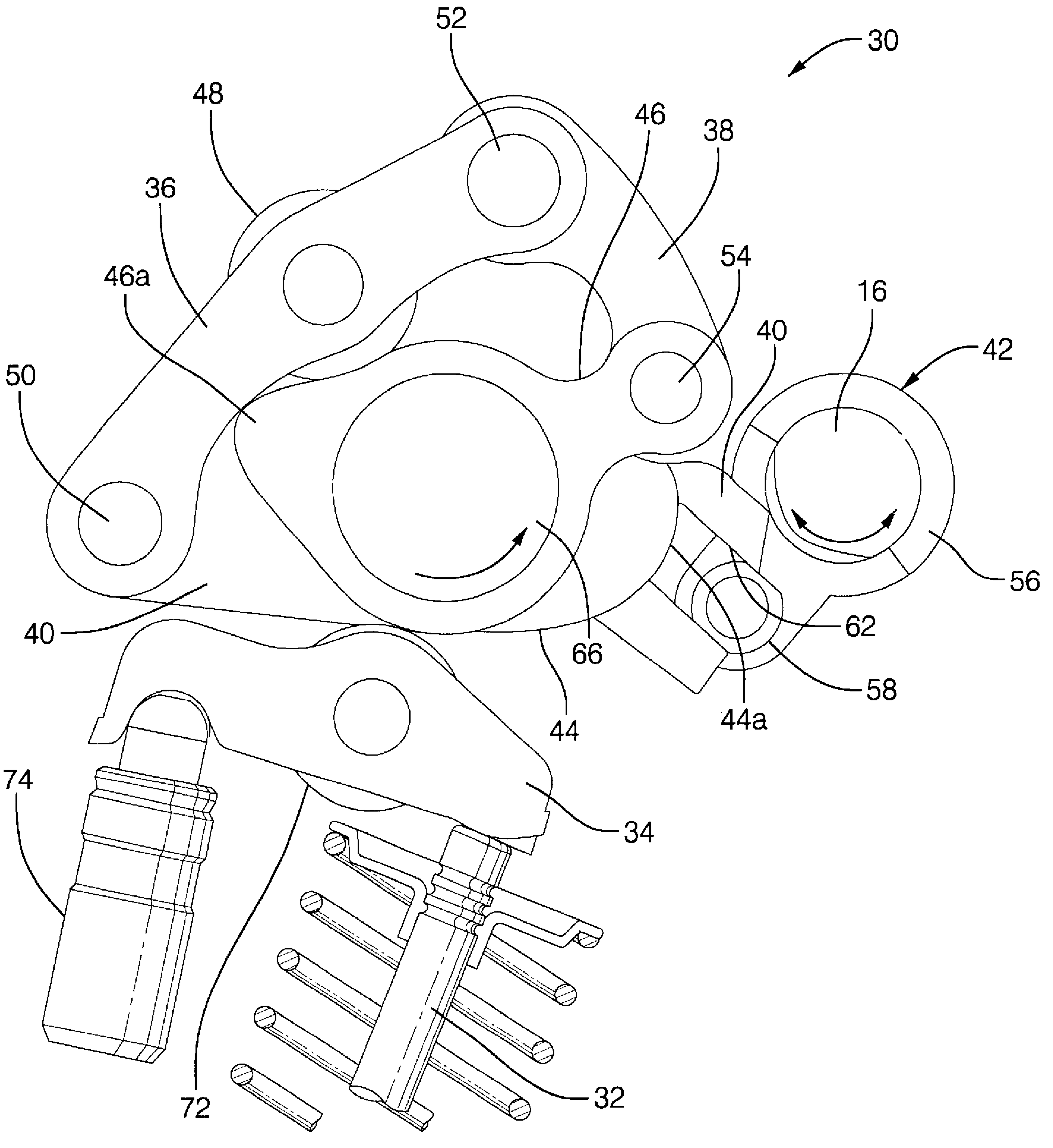


FIG. 3

VARIABLE VALVE ACTUATOR ASSEMBLY HAVING A SECONDARY ACTUATOR

TECHNICAL FIELD

The present invention relates generally to variable valve trains of internal combustion engines and, more particularly, to actuating assemblies of variable valve trains.

BACKGROUND OF THE INVENTION

Conventional internal combustion engines utilize two throttling devices, i.e., a throttle valve and the intake valves of the engine. The throttle valve is actuated by a driver depressing and/or releasing the gas pedal, and regulates the air flow to the intake valves. The engine intake valves are driven by the camshaft of the engine. The intake valves open and close at predetermined angles of camshaft rotation to allow the descending piston to draw air into the combustion chamber. The opening and closing angles of the valves and the amount of valve lift is fixed by the cam lobes of the camshaft. The valve lift profile (i.e., the curve of valve lift plotted relative to rotation of the camshaft) of a conventional engine is generally parabolic in shape.

Modern internal combustion engines may incorporate more complex and technologically advanced throttle control systems, such as, for example, electronically controlled throttle systems and intake valve throttle control systems. Electronically controlled throttle systems, in general, eliminate the mechanical link between the gas pedal and the upstream throttle by substituting an electronic sensor to communicate driver input (i.e., gas pedal position) to an engine control module. The engine control module, in turn, electronically controls the position of the upstream throttle. Intake valve throttle control systems, in general, control the flow of gas and air into and out of the cylinders of an engine by varying the timing and/or lift (i.e., the valve lift profile) of the intake valves in response to engine operating parameters, such as, for example, engine load, speed, and driver input. Intake valve throttle control systems vary the valve lift profile through the use of various mechanical and/or electro-mechanical configurations, generally referred to herein as variable valve mechanisms. Examples of a variable valve mechanisms are detailed in commonly-assigned U.S. Pat. No. 5,937,809, the disclosure of which is incorporated herein by reference. Generally, and as will be described more particularly hereinafter, a variable valve mechanism includes a control shaft that is rotatable by an actuator to thereby vary valve timing, duration and lift.

Despite the advanced technology used in and the reliability of modern throttle control systems, the contingency of malfunction and even failure must be considered. Malfunction and/or failure of the actuator of a variable valve mechanism results in the engine either stalling completely or, at best, continuing to run at a very low output level due to an improper air-to-fuel ratio. A variable valve mechanism having a failed actuator will be unresponsive to driver input seeking to actuate the throttle in order to increase speed or engine output. Thus, the operator of the vehicle may be unable to restart the vehicle, to "limp home", or to drive to the nearest repair station.

The actuator in a variable valve mechanism must be capable of providing a minimum angular rotation within a maximum period of time in order to provide appropriate response to driver input and to achieve satisfactory system performance. In order to conform to such a specification, an actuator may sacrifice resolution, i.e., the capability of

making small or fine adjustments in rotational position, in the interest of rotational speed. Thus, the actuator may not be capable of making fine adjustments in the angular position of the control shaft. A variable valve mechanism having such an actuator may be incapable of finely tuning the valve lift profile. Inability to finely tune the valve lift profile can result in rough engine idle and a decrease in system and/or engine efficiency.

Therefore, what is needed in the art is an apparatus that provides a limp home capability to a variable valve mechanism.

Furthermore, what is needed in the art is an apparatus that provides driver control over a variable valve mechanism having a failed main actuator.

Moreover, what is needed in the art is an apparatus that provides the capability to finely tune and/or adjust the valve lift profile of a variable valve mechanism.

SUMMARY OF THE INVENTION

The present invention provides a variable valve actuating assembly including a secondary actuator.

The invention comprises, in one form thereof, a variable valve actuator assembly including a main actuator, a secondary actuator and an actuator shaft. The actuator shaft is coupled to each of the main actuator and the secondary actuator. The main actuator and the secondary actuator are each separately and independently selectable for rotating the actuator shaft.

An advantage of the present invention is that the secondary actuator provides for actuation of the control shaft, and thereby adjustment of the valve lift profiles, in the event of a failure of the main actuator.

Another advantage of the present invention is that the secondary actuator enables fine tuning of the valve lift profiles under engine idle conditions.

A still further advantage of the present invention is that the secondary actuator enables a driver to restart and drive a vehicle having an engine in which the main actuator has failed.

BRIEF DESCRIPTION OF THE DRAWINGS

The above-mentioned and other features and advantages of this invention, and the manner of attaining them, will become apparent and be better understood by reference to the following description of one embodiment of the invention in conjunction with the accompanying drawings, wherein:

FIG. **1** is a block diagram of the variable valve actuator assembly having a main actuator and a secondary actuator of the present invention;

FIG. **2** is a perspective view of a variable valve mechanism in a maximum lift position; and

FIG. **3** is a perspective view of a variable valve mechanism in a minimum lift position.

Corresponding reference characters indicate corresponding parts throughout the several views. The exemplification set out herein illustrates one preferred embodiment of the invention, in one form, and such exemplification is not to be construed as limiting the scope of the invention in any manner.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings and particularly to FIG. **1**, there is shown one embodiment of a variable valve actuator assembly having a secondary actuator of the present invention.

Variable valve actuator assembly **10** includes actuator shaft **11**, main actuator **12**, main output gear **12***a*, secondary actuator **14** having secondary output gear **14***a*, secondary shaft gear **15**, control shaft **16** and control shaft gear **16***a*.

Main actuator **12** selectively drives rotation of control shaft **16**. More particularly, main actuator **12** selectively rotates actuator shaft **11**. The rotation of actuator shaft **11** is transferred, via main output gear **12***a* and control shaft gear **16***a*, to control shaft **16**. Main actuator **12** also drives secondary output gear **14***a* via secondary shaft gear **15** under normal engine operating (i.e., non-failure and/or non-idle) conditions. Secondary actuator **14** and secondary output gear **14***a* are capable of being driven in a forward and backward direction by the rotation of actuator shaft **11**. Main actuator **12** is selected to be appropriately powered such that it is capable of driving both control shaft **16** and secondary actuator **14**, so long as secondary actuator **14** is in an unpowered condition, throughout the entire range of anticipated operating parameters of internal combustion engine **17**. Further, main actuator **12** is selected such that it is capable of rotating control shaft **16** through a minimum range of rotation within a desired maximum response time, such as, for example seventy-two degrees of rotation of control shaft **16** within 300 mS. Main actuator **12** is, for example, a direct current (DC) motor driving a gear box (not shown) which, in turn, drives main output gear **12***a* and secondary shaft gear **15**.

Main output gear **12***a* is, for example, formed integrally with or fixedly secured to actuator shaft **11**. Main output gear **12***a* is driven to rotate by main actuator **12**. Main output gear **12***a* is, for example, a self locking, single pitch worm gear. Main output gear **12***a* has self-locking gear teeth **20** formed thereon. Teeth **20** are relatively widely spaced, and therefore main output gear **12***a* has a relatively large circular pitch (circular pitch is defined as the distance from the center of one tooth to the center of the next tooth as measured at the circumference of the pitch circle). Main output gear **12***a* engages engage control shaft gear **16***a*. As main output gear **12***a* is rotated teeth **20** engage teeth (not shown) on control shaft gear **16***a* to thereby rotate control shaft **16**.

Secondary actuator **14** is also capable of selectively driving the rotation of control shaft **16**. More particularly, secondary actuator **14** drives secondary output gear **14***a* which, in turn, drives secondary shaft gear **15** and rotates actuator shaft **11**. The rotation of actuator shaft **1** is transferred, via main output gear **12***a* and control shaft gear **16***a*, to control shaft **16**. Secondary actuator **14** is configured as, for example, a direct current (DC) motor driving a gear box (not shown) which, in turn, drives secondary output gear **14***a*. Secondary actuator **14** is capable of driving secondary output gear **14***a* in a forward and a backward direction, and is thus capable of rotating control shaft **16** in either a forward or backward direction. Secondary actuator **14** is selected to be adequately powered to rotate control shaft **16** and main actuator **12**, so long as main actuator **12** is in an unpowered condition.

Secondary output gear **14***a* includes non-locking gear teeth **22**. Teeth **22** are closely-spaced relative to teeth **20** of main output gear **12***a*. For example, secondary output gear **14***a* has four times as many teeth per inch relative to main output gear **12***a* and therefore has a small circular pitch relative to main output gear **12***a*. Thus, secondary actuator **14**, driving secondary output gear **14***a* having finely-spaced teeth **22**, has a substantially higher resolution and rotates control shaft **16** in substantially smaller increments than main actuator **12**. Conversely, main actuator **12** rotates control shaft **16** in relatively large increments by driving main output gear **12***a* having relatively widely-spaced gear teeth **20**. Under engine idle operating conditions, higher-resolution secondary actuator **14** is used to fine tune the valve lift profile of engine **17** by adjusting in small increments the position of control shaft **16**, as initially and approximately set by main actuator **12**. Further, the relatively fine spacing of gear teeth **22** enable secondary actuator **14** to be of a lower power than main actuator **12**, and thus of lighter weight.

Secondary shaft gear **15** is, for example, formed integrally with or fixedly secured to actuator shaft **11**. Secondary shaft gear **15** engages secondary output gear **14***a*. Control shaft **16** is coupled to main output gear **12***a* by control shaft output gear **16***a*.

Referring now to FIGS. **2** and **3**, control shaft **16** extends axially from main output gear **12***a* and is coupled, as will be explained more particularly hereinafter, to variable valve mechanism **30**. Thus, variable valve actuator assembly **10** is coupled to variable valve mechanism **30**. It should be noted that the structure and elements of variable valve mechanism **30** are presented for the purpose of illustrating the operation and interrelationship of variable valve actuator assembly **10** with one embodiment of a variable valve mechanism. Further, it should be noted that actuator assembly **10** may be coupled to numerous and differently-configured variable valve mechanisms, and that the particular configuration of variable valve mechanism **30** is not to be construed as limiting the application of variable valve actuator assembly **10** to any particular configuration of variable valve mechanism.

Variable valve mechanism **30** includes valve **32**, roller finger follower (RFF) **34**, primary lever or rocker **36**, link **38**, control member **40**, control shaft linkage **42**, rotary cam **44** and oscillating cam **46**. Variable valve mechanism **30** reciprocates valve **32**. Valve **32** is, for example, an intake valve of internal combustion engine **17**.

Primary rocker **36** includes rotary roller **48**, frame pivot pin **50** and link pin **52**. Rotary roller **48** is attached to and carried by primary rocker **36**. Rotary roller **48** is engaged by rotary cam **44**, as will be described in more detail hereinafter. Frame pivot pin **50** pivotally couples primary rocker **36** to control member **40** (only a portion of control member **40** is shown in FIG. **2** for clarity). Link pin **52** couples primary rocker **36** to link **38** which, in turn, is coupled to oscillating cam **46** via oscillating cam pin **54**.

Control shaft linkage **42** includes control shaft clamp **56** and control shaft crank pin **58**. Control shaft linkage **42** couples control shaft **16** to variable valve actuator assembly **10**. Control shaft clamp **56** is attached to control shaft **16**, such as, for example, by clamping. Control shaft crank pin **58** is attached to and carried by control shaft clamp **56**, and is received within slot **62** of control member **40**.

Control member **40** is rotationally mounted to camshaft **66**. Control member **40** is not rotated by camshaft **66**, but does rotate around the central axis (not referenced) of camshaft **66**. Control member **40** is coupled to primary rocker **36** via frame pivot pin **50**, and is coupled to control shaft linkage **42** via control shaft crank pin **58**. The portion of control member **40** that is coupled to primary rocker **36** at pivot pin **50** has been omitted from FIG. **2** for the sake of clarity.

Rotary cam **44** is coupled to or formed integrally with camshaft **66**. Thus, the rotation of camshaft **66** results in a corresponding rotation of rotary cam **44**. Rotary cam **44** includes rotary cam lobe **44***a*. Rotation of rotary cam **44**, in turn, displaces rotary roller **48** according to the lift profile of rotary cam lobe **44***a*.

Oscillating cam **46** is rotationally mounted upon camshaft **66**. Oscillating cam **46** is rotatable relative to and around the central axis (not referenced) of camshaft **66**. However, oscillating cam **46** is not rotated by camshaft **66**. Rather, oscillating cam **46** is rotated via the rotation of rotary cam **44**. More particularly, as rotary cam **44** rotates, rotary cam lobe **44***a* engages rotary roller **48**. Primary rocker **36** is displaced in a generally-radial direction relative to camshaft **66** according to the lift profile of rotary cam lobe **44***a*. The displacement of primary rocker **36**, in turn, is transferred via link pin **52** to a corresponding displacement of link **38**. The displacement of link **38** is transferred by oscillating cam pin **54** to a corresponding degree of rotation of oscillating cam **46** relative to the central axis of camshaft **66**. Thus, the amount by which oscillating cam **46** rotates about the central axis of camshaft **66** is determined by the lift profile of rotary cam lobe **44***a*.

In use, variable valve actuator assembly **10** determines the valve lift profile of valve **32** of variable valve mechanism **30**. In general, the valve lift profile of valve **32** is determined or initially set by the rotation of control shaft **16** by main actuator **12** to thereby place oscillating cam lobe **46***a* and follower roller **72** in a predetermined angular/rotational relationship (i.e., the rotational proximity of oscillating cam lobe **46***a* and follower roller **72** is determined by the rotation of control shaft **16**). More particularly, rotation of control shaft **16** rotates control shaft linkage **42**. Rotation of control shaft linkage **42** is transferred by control shaft crank pin **58** to control member **40** to thereby establish a predetermined rotational position of control member **40** relative to the central axis of camshaft **66** (as stated above, only a portion of control member **40** is shown in FIG. **2** for clarity). The rotation of control member **40** is transferred through frame pivot pin **50** to a corresponding rotation of primary rocker **36** relative to camshaft **66**. The rotation of primary rocker **36** is transferred through link pin **52** to rotation of link **38**. The rotation of link **38** is transferred by oscillating cam pin **54** to rotation of oscillating cam **46** to thereby establish the rotational position of oscillating cam lobe **46***a* relative to follower roller **72**. Once the desired position of oscillating cam lobe **46***a* relative to follower roller **72** is established, the rotation of control shaft **16** is ceased. Control shaft **16** maintains oscillating cam **46** in the desired position by precluding the rotation of control member **40** about the central axis of camshaft **66**.

The valve lift profile of valve **32** is determined by the angular/rotational proximity of oscillating cam lobe **46***a* to follower roller **72** and, thus, by the rotation of control shaft **16**. By comparing the angular position of oscillating cam lobe **46***a* relative to follower roller **72** in FIG. **2** to the angular position of oscillating cam lobe **46***a* relative to follower roller **72** in FIG. **3**, the effect of the angular or rotational proximity of oscillating cam lobe **46***a* to follower roller **72** upon the valve lift profile is readily understood. Referring now specifically to FIG. **2**, it is seen that oscillating cam lobe **46***a* is positioned in relatively close rotational/angular proximity to follower roller **72**. Thus, a relatively slight rotation, such as, for example, forty degrees, of oscillating cam **46** results in a substantial portion of oscillating cam lobe **46***a* engaging follower roller **72**. The engagement of follower roller **72** by oscillating cam lobe **46***a* causes RFF **34** to pivot about lash adjuster **74**. The amount of pivot of RFF **34** corresponds to the portion of oscillating cam lobe **46***a* which engages follower roller **72**. The pivoting of RFF **34**, in turn, causes a corresponding displacement or reciprocation of valve **32**. In fact, with oscillating cam lobe **46***a* positioned relative to follower roller **72** as shown in FIG. **2**, oscillating cam lobe **46***a* engages follower roller **72** up to approximately the peak (not referenced) of oscillating cam lobe **46***a* thereby resulting in a substantial pivoting of RFF **34** and a correspondingly substantial amount of displacement of valve **32**.

In contrast, and as shown in FIG. **3**, oscillating cam lobe **46***a* is positioned relatively distant from follower roller **72**. Thus, a relatively slight rotation, such as, for example, forty degrees, of oscillating cam **46** results in the base circle (i.e., the zero lift portion) of oscillating cam **46** engaging follower roller **72** for a substantial portion of the rotation of oscillating cam **46**. Only the zero lift portion or a low lift portion of output cam lobe **46***a* engages follower roller **72** during the rotation of oscillating cam **46**. Thus, follower roller **72** is displaced only slightly due to only the zero or low-lift portion of oscillating cam lobe **46***a* engaging follower roller **72**. Therefore, valve **32** is displaced or reciprocated a correspondingly slight amount.

Actuation of valve **32** is accomplished indirectly by the rotation of rotary cam **44**. Rotary cam **44** is rotated a full 360 degrees (three-hundred sixty degrees) by camshaft **66**. Rotary cam **44** engages rotary roller **48**. As rotary cam **44** is rotated by camshaft **66**, rotary roller **48** is displaced according to the lift profile of input cam **44**. The displacement of rotary roller **48** causes a corresponding displacement of primary rocker **36**. The displacement of primary rocker **36** is transferred to link **38** via link pin **52**. Thus, primary rocker **36** pulls link **38** in a generally-axial direction. The pulling of link **38** is transferred through output cam pin oscillating cam pin **54** to oscillating cam **46**, thereby causing oscillating cam **46** to rotate about camshaft **66** an amount corresponding to the lift profile of rotary cam **44**. Oscillating cam **46** engages roller follower **72**. Follower roller **72** is displaced according to the lift profile of that portion of oscillating cam **46** which engages follower roller **72**. As described above, the portion of the lift profile of oscillating cam **46** which engages follower roller **72** is determined by the rotational proximity of oscillating cam lobe **46***a* relative to follower roller **72** as established by the rotation of control shaft **16**. A return spring (not shown) pulls or returns primary rocker **36** and oscillating cam **46** to thereby place oscillating cam lobe **46***a* into the angular/rotational position as determined by the rotational position of control shaft **16**.

As described above, main actuator **12** determines the valve lift profile of variable valve mechanism **30** by setting the position of oscillating cam lobe **46***a* relative to follower roller **72** through the rotation of control shaft **16**. Thereafter, primary actuator **12** is depowered. Secondary actuator **14** thereafter rotates control shaft **16** to make fine adjustments in the rotational position of oscillating cam lobe **46***a* relative to follower roller **72**. Further, in the event of a failure of main actuator **12**, secondary actuator **14** is used to provide limited control over the valve lift profile of variable valve mechanism **30** and to provide a limp home capability. Secondary actuator **14** rotates control shaft **16** by rotating secondary output gear **14***a*. Rotation of secondary output gear **14***a* is transferred through secondary shaft gear **15** and actuator shaft **11** to rotation of main output gear **12***a*. Rotation of main output gear **12***a* is transferred via control shaft gear **16***a* to control shaft **16** to thereby adjust the rotational position of oscillating cam lobe **46***a* relative to follower roller **72** and, thus, the valve lift profile of variable valve mechanism **30**.

The fine adjustment in the valve lift profile of variable valve mechanism **30** is performed by secondary actuator **14** when main actuator **12** is depowered and in response to, for example, electrical signals received from an engine control unit or computer (not shown). Secondary actuator **14** performs this fine adjustment, for example, under engine idle operating conditions. The fine adjustment or fine tuning is enabled by virtue of the relatively fine gear teeth **22** of secondary output gear **14***a*. Further, secondary actuator **14** rotates control shaft **16** to adjust the rotational position of oscillating cam lobe **46***a* relative to follower roller **72**, and thereby adjust the valve lift profile of variable valve mechanism **30**, under a range of engine operating conditions to maximize the efficiency of variable valve mechanism **30** and engine **17**.

Upon failure of main actuator **12**, secondary actuator **14** is used to provide driver control of the intake valve throttle control system. Failure of main actuator **12** or failure of control shaft **16** to rotate is detected by, for example, an engine control module via a sensor (neither of which are shown). Upon detecting a failure of main actuator **12** or a failure of control shaft **16** to rotate, the engine control module routes signals containing, for example, a stall indication, driver input and/or reset information to secondary actuator **14**. Secondary actuator **14** rotates control shaft **16** in response to the signals from the engine control unit. Thus, if engine **17** has stalled due to, for example, a failure of main actuator **12**, secondary actuator **14** is commanded to return the valve lift profile to a stall-recovery, engine restart, or idle position. Secondary actuator **14** responds by rotating control shaft **16** to thereby appropriately position oscillating cam lobe **46***a* relative to follower roller **72**, and thereby set the valve lift profile of variable valve mechanism **30**, for restarting engine **17**. Once engine **17** is restarted, driver input is routed by the engine control unit to secondary actuator **14**, which responds by adjusting the valve lift profile of variable valve mechanism **30** according to the driver input. Thus, secondary actuator **14** provides driver control over variable valve mechanism **30** in the event of a failure of main actuator **12** thereby enabling a driver to restart the vehicle, to "limp home", or to drive to the nearest repair station.

As stated above, secondary actuator **14** may optionally be selected to be of lower power and/or slower response speed than main actuator **14**. Thus, the only effect noticeable by a driver due to the failure of main actuator **12** would be a decrease in the responsiveness of the throttle control system. In addition, a trouble indicator light or service engine soon light can be illuminated. If size, power, and weight constraints permit, secondary actuator **14** may be selected to be of sufficient power such that the effect of a failure of main actuator **12** would be minimally, if at all, perceptible to a driver without the illumination of a trouble indicator light.

In the embodiment shown, each of main actuator **12** and secondary actuator **14** are configured as DC motors. However, it is to be understood that the main actuator and secondary actuator may be alternately configured, such as, for example, hydraulic actuators.

In the embodiment shown, secondary actuator **14** is selected to be of lower power than main actuator **12**. However, it is to be understood that secondary actuator **14** may be alternately configured, such as, for example, of the same power or higher powered than main actuator **12**.

In the embodiment shown, main actuator **12** and secondary actuator **14** are configured as separate and distinct actuators. However, it is to be understood that the main actuator and secondary actuator may be alternately configured, such as, for example, separate windings within a single motor.

In the embodiment shown, secondary output gear **14***a* has, for example, four times as many teeth per inch relative to main output gear **12***a* and therefore has a small circular pitch relative to main output gear **12***a*. However, it is to be understood that secondary output gear **14***a* can be alternately configured, such as, for example, as having approximately the same circular pitch as main output gear **12***a* to having a substantially smaller circular pitch relative thereto.

While this invention has been described as having a preferred design, the present invention can be further modified within the spirit and scope of this disclosure. This application is therefore intended to cover any variations, uses, or adaptations of the present invention using the general principles disclosed herein. Further, this application is intended to cover such departures from the present disclosure as come within the known or customary practice in the art to which this invention pertains and which fall within the limits of the appended claims.

What is claimed:

1. A variable valve mechanism, comprising:

a control shaft, said control shaft being rotatable to select a desired valve lift profile of at least one valve in said variable valve mechanism; and

a variable valve actuator assembly, including;

- a main actuator;
- a secondary actuator; and
- an actuator shaft coupled to each of said main actuator and said secondary actuator, said main actuator and said secondary actuator each being separately and independently selectable for driving said actuator shaft to rotate, said actuator shaft being coupled to said control shaft such that rotation of said actuator shaft is transferred to said control shaft.

2. The variable valve mechanism of claim **1**, wherein each of said main actuator and said secondary actuator comprise respective motors.

3. The variable valve mechanism of claim **1**, wherein said main actuator and said secondary actuator comprise separate windings within a single motor.

4. The variable valve mechanism of claim **1**, further comprising a main output gear, said main output gear coupling said actuator shaft to said control shaft such that rotation of said actuator shaft is transferred to said control shaft.

5. The variable valve mechanism of claim **4**, further comprising a secondary output gear, said secondary output gear being selectively and directly driven to rotate by said secondary actuator, said secondary output gear being coupled to said actuator shaft such that rotation of said secondary output gear is transferred to said actuator shaft.

6. The variable valve mechanism of claim **5**, further comprising a secondary shaft gear disposed on said actuator shaft, said secondary shaft gear coupling said secondary output gear to said actuator shaft.

7. The variable valve mechanism of claim **6**, wherein said main output gear includes a plurality of first gear teeth having a first circular pitch, said secondary output gear includes a plurality of second gear teeth having a second circular pitch, said second circular pitch being less than said first circular pitch.

8. The variable valve mechanism of claim **7**, wherein said second circular pitch is from approximately one-half to approximately one-tenth of said first circular pitch.

9. The variable valve mechanism of claim **1**, wherein said secondary actuator is selected to be at least one of a lower power, smaller size and lighter weight than said main actuator.

10. An internal combustion engine, comprising:

a variable valve train mechanism having at least one intake valve;

a control shaft coupled to said variable valve mechanism, said control shaft being rotatable to select a desired valve lift profile of said at least one valve; and

a variable valve actuator assembly, including;

a main actuator;

a secondary actuator; and

an actuator shaft coupled to each of said main actuator and said secondary actuator, said main actuator and said secondary actuator each being separately and independently selectable for driving said actuator shaft to rotate, said actuator shaft being coupled to said control shaft such that rotation of said actuator shaft is transferred to said control shaft.

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